Li solution of the steady-state problem of tokamak in the light of the last experimental results

S.V.Mirnov[1,3,4], A.S.Dzhurik[1], A.T.Komov[4],V.B.Lazarev[1], I.E. Lyublinski[2,3], V.G.Otroshchenko[1], A.N. Shcherbak[1], A.N.Varava[4], Ya. A.Vasina[3], A.V.Vertkov[2], A.V.Zaharenkov[4], M.Yu. Zharkov[2]

[1]*JSC "SSC RF TRINITI" 108 840RussiaMoscowTroitsk Dep. Pushkovih St 12,*
[2]*JSC «Red Star», 113230, Russia, Moscow, Elektrolitny dr. 1A,*
[3]*NRNU MEPhI, 115409, Russia, Moscow, Kashirskoe sh.,31,*
[4]*NRU MPEI, 111250, Russia, Moscow, Krasnokasarmennaya St.,14*

The lastT-11M experiments [1] have led to an important practical conclusions about the lithium and hydrogen capture by a hot CPS collector filled with liquid lithium. The preferable temperature interval for the efficient capture of lithium ions by a liquid-lithium-filled CPS is 200–350°C, while for the efficient capture of deuterium, it is 200–300°C. For the efficient removal of deuterium (and probably tritium) from liquid lithium (DT recuperation), heating up to 500–550°C will be sufficient. The next important result of T-11M experiments with a heated SS target, which modeled the wall of the FNS chamber, is that the capture of lithium and hydrogen isotopes by films deposited on the target surface in the course of a plasma discharge hard depends on the temperature of the target. Namely, after heating of the target to 300–400°C, the hydrogen capture practically disappears, although the lithium capture decreases only three- to four fold. Thus, if the first wall of the FNS, permanently protected by the lithium film, will be heated to 400°C, it will play the role of a "mirror" with respect to deuterium and tritium ions incident on it. As a result, the total amount of tritium circulating in such a lithium–fuel circuit can be reduced to a minimal level. The temperatures indicated by the main elements of the scheme in figure 1 correspond to the recommended temperature ranges of their steady-state operation

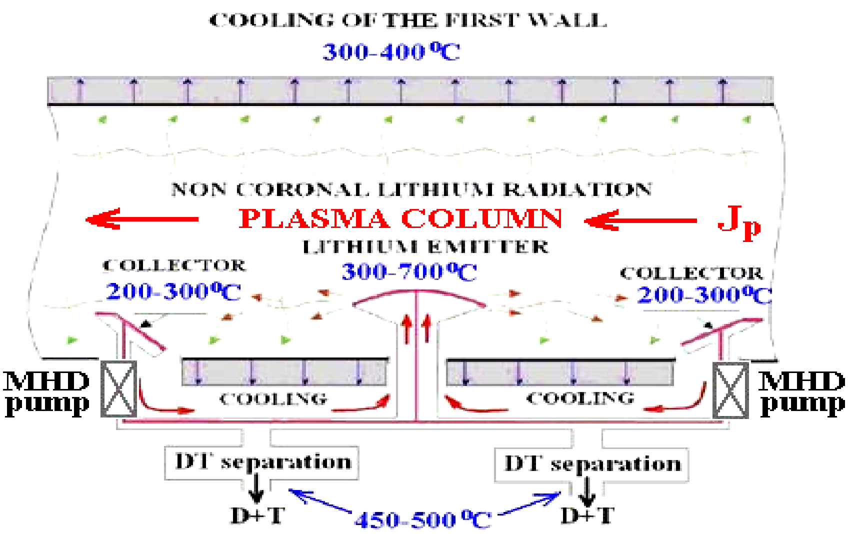


Figure 1. Schematic diagram of the Li and DT circulation loop in a steady-state tokamak

As we can see from figure 1 the main active elements of a closed loop of lithium circulation should operate in a wide temperature range from 200 to 700 °C. The various coolers are required to control all thermal field of the lithium circuit. The traditional water flow cooling would require the use of cooling equipment operating in the pressure range from $2{,}10^6$ to 10^7 Pa, which seems to be an overly expensive and dangerous device. To solve this problem was proposed by [2] to change the flow of water as cooler to the spray gas-water, which would allow to overcome the crisis of boiling and thereby to reduce the pressure in the cooling system of the lithium emitters and collectors of the tokamak. Figure 1 presents a schematic diagram of a gas-water cooler, which has as main elements a spray generator with a spray nozzle.

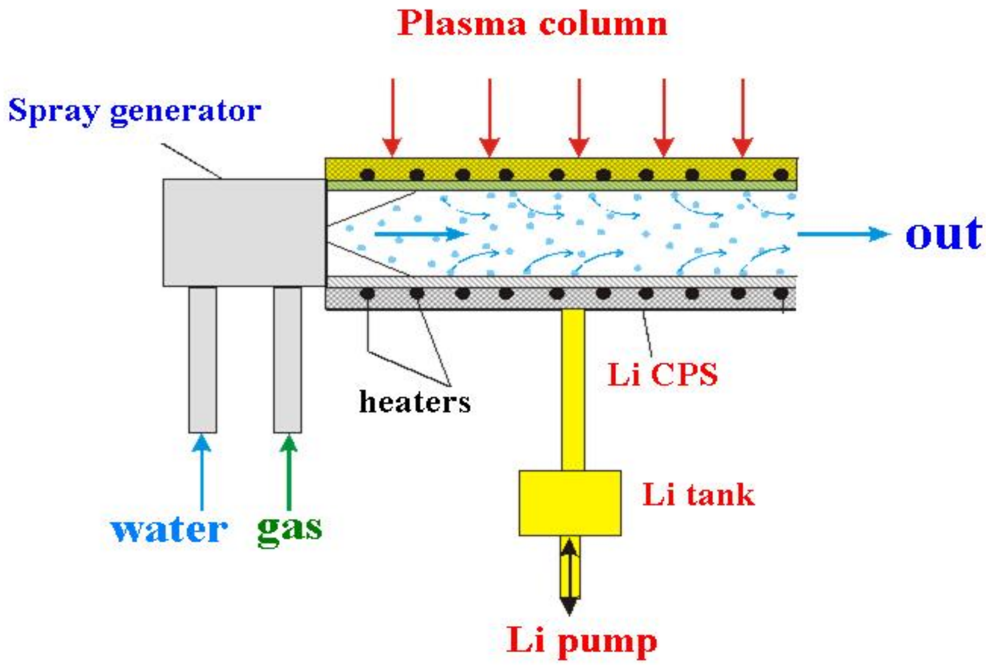


Figure 2. Schematic diagram of a gas-water cooler

To check the effectiveness of this idea the Moscow power engineering Institute (NRU MPEI), JSC «Red Star» and JSC "SSC RF TRINITI" with the support of the Russian Science Found (RSF grant № 16-19-10457) created a working model, which simulated the operation of the lithium emitter of the tokamak T-10 with the cooling by gas-water spray [2]. A copper tube with thermocouples (figure 3) was used as an analogue of the cooling channel of the active element of the lithium circuit interacting with the plasma.

It was heated by an electron beam generator (figure 4), which allowed simulating a local load on the surface of the target up to 12MW/m^2. The experiment demonstrated high efficiency of cooling the target surface with gas-water spray.

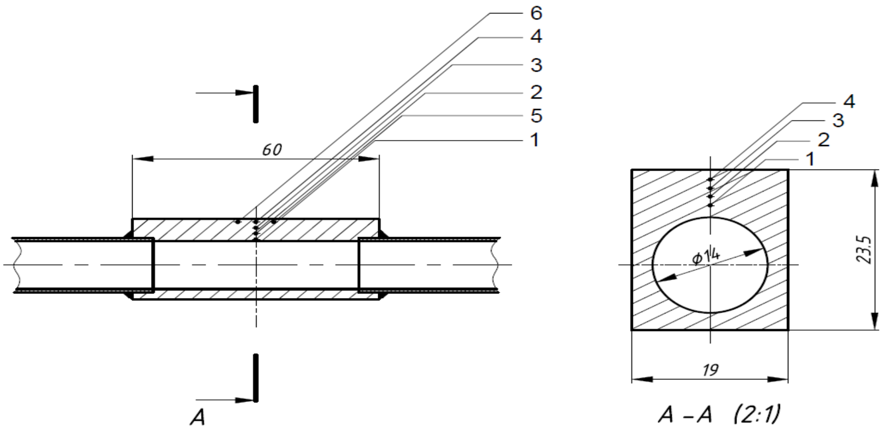
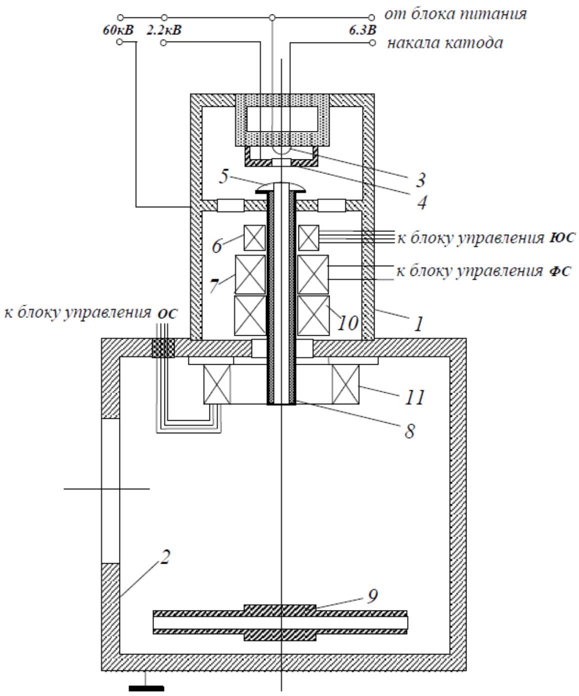


Figure2. Test section. Thermocouples position



1 – electronic gun
2 – vacuum chamber
3 – cathode
4 – control electrode
5 – control anode
6 – regulate coils
7 – focusing system
8 – laser beam guide
9 – test section target
10 – sweep unit
11 – deflecting coils

Figure 2. Principle circuit of controller electronic gun.

Figure 4 shows the evolution of the target temperature by increasing the heat load to its outer wall up 4 to 11MW /m^2, which is approximately consistent with the plasma loads on the lithium collectors in real tokamaks.

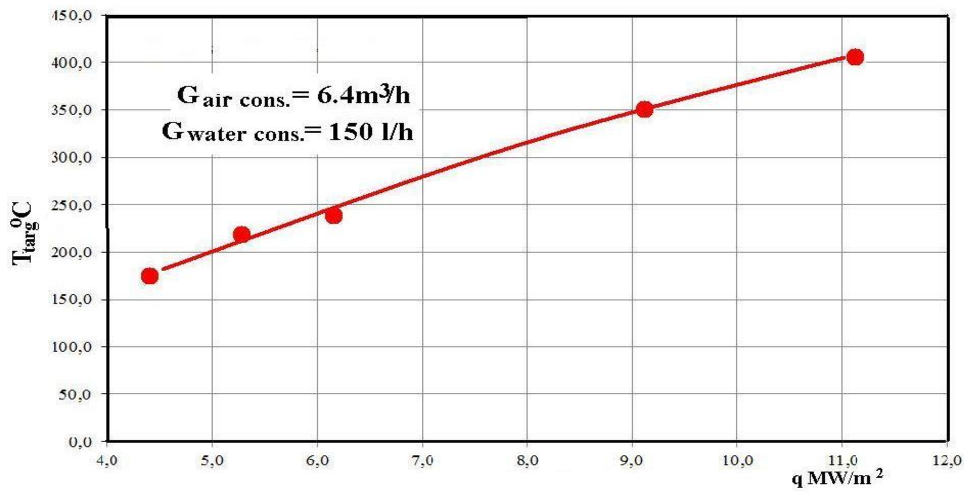


Figure 4. Sample of target temperature increase from power load in the regime of gas-water operation with air consumption 6.4 m^3/h and water consumption 150 l/h

Figure 5 shows one of the variants of cooling the vertical lithium emitter tokamak T-15 as an example.

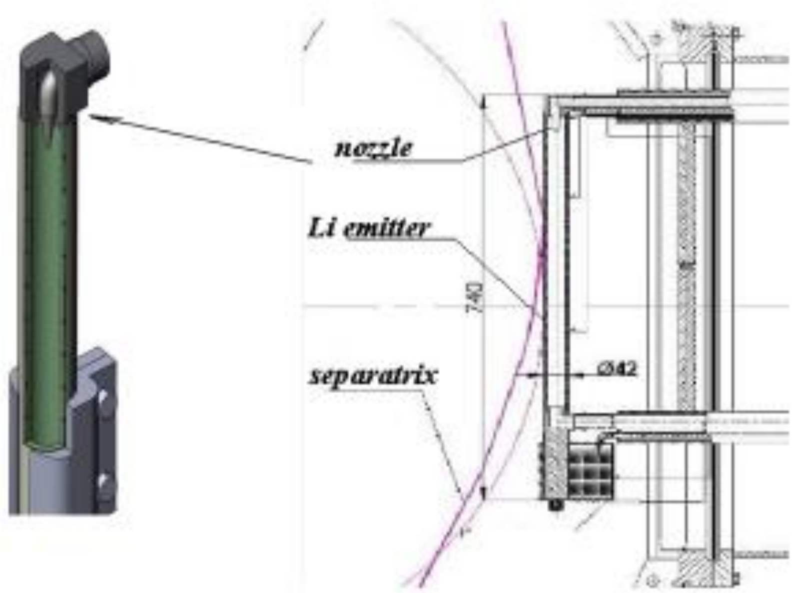


Figure 5. One version of gas-liquid cooling of tokamak T-15 Li emitter

The work supported by RSF grant № 16-19-10457

[1] A.N.Shcherbak, S.V.Mirnov e.a. 44 EPS Conf. on Plasma Phys. (2017, Belfast), **P5 112**

[2] [2] A.V.Vertkov, A.T.Komov, I.E.Lyublinski et al. Voprosi atomnoi nauki i tehniki. Termojadernii sintes (Rus.) (2018) v41 N 1 57-64.